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Evaluation of Ionizing Radiation Profile in Hot-Lab of Nuclear Medicine Department to Eliminate Undue Radiation Phobia of Technologists in Cancer Hospital

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ABSTRACT

The risks related to the radiation exposures cannot be eradicated, but can be minimized by implementing radiation safety culture in the hot-labs. This study aimed to measure background radiation levels in hot-laboratory, arguably the area with the highest radiation level, where all radiopharmaceuticals are prepared in a cancer hospital.Ten distinct locations inside the hot-lab were periodically monitored with a pre-calibrated RM1001-RD LAMSE radiation survey meter for the period of one year. Daily dose rates were recorded and AEDR was calculated using standard notations. The dose rates on selected points were found ranging from 0.12 to 0.21 μSv/h while the Annual Effective Doses were found a maximum rate of 1.47±0.04 mSv/y and minimum 0.85 ± 0.03 mSv/y. These findings show t-test values with a level of significance of 5% ($P<0.05$). It is concluded that the dose rates in our setup are negligible as per the NRC dose limit of 20 μSv/h and AEDR is about 58% of the radiation limit of 2.4 mSv/y recommended by UNSCEAR. Therefore, the hot-lab technologist is radio-biologically safe inside hot-lab with this setup having strict compliance with radiation protection protocols. This study give some findings about undue radiophobia in the hot-lab technologists worked in the Nuclear Medicine departments of cancer hospitals.

Keywords: Background Radiation, Effective Dose, Equivalent Dose, Survey Monitor, SSDL, Hot-lab, Radiopharmaceutical, AEDR

1. Introduction

It is a proven fact that the phenomenon of radiation has certain cons along with its pros. On the one hand, it is beneficial if used intelligently and on the other hand, it is harmful to living beings. In the nuclear medicine department of cancer hospitals, we deal with many kinds of radiation with varying intensity levels in everyday activities. Commonly observed risks associated with radiation include cancer, genetic mutation, cataract, degradation of blood cells and skeletal bones etc. The severest consequence entails death of individuals if radiation is imparted in enough quantity in terms of dose [1]. Radiation is also being used for the treatment of cancer worldwide [2]. Every nuclear medicine facility in the world utilizes a few common radionuclides e.g., ^{99m}Tc, ^{131}I, ^{57}Co, ^{137}Cs, ^{125}I, ^{90}Sr, and ^{32}P etc. for diagnosis as well as treatment of different types of cancers. These radionuclides are also used for the calibration of diagnostic modalities as well as academic and research activities. Radiation consists of energetic particles that have ability to interact with the matter [3]. They also interact with human body and cause potential harm. There are regulatory bodies on global as well as local levels that clearly state that there is no minimum radiation level that we may consider safe. Radiation has somatic as well as genetic effects including formation of

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cancers along with congenital anomalies [4]. A few effects of ionizing radiation on the human health are well known, yet some other are still controversial. The issue becomes more pertinent in the case of radiation technologists that work in the nuclear medicine departments. These technologists have to handle all types of radiation sources while working in hot-lab. Their job description involves managing all sorts of radionuclides whether used for therapy, calibration or diagnostic purposes. Thus, the Radiation Protection representatives must have knowledge of radiation effects and processes to mitigate these effects in the nuclear medicine workplaces to minimize health-associated risks [5]. Since the practices in nuclear medicine involve bare-handling of radionuclides, it requires special radiation protection SOPs(standard operating procedures) in these procedures to lower the radiation exposure of nuclear medicine workers [6]. The key purpose of radiation-protection practices is to avoid the drastic effects of radiation by managing keep radiation doses lower than threshold levels and also to minimize the chances of occurrence stochastic effects [7].

It is essential to maintain and review the dose record of the staff working with un-sealed radioactive materials to keep track of personnel doses. For this reason, the working environment is divided into controlled and supervised areas depending upon the level of radiation present there. This study contains ten potential radiation locations inside the hot-lab of nuclear medicine department of NORIN (The Nuclear Medicine Oncology and Radiotherapy Institute Nawabshah) Nawabshah. All radiopharmaceuticals for nuclear medicine department are received, stored, prepared, tagged and dispensed in the hot-lab [8]. The hot-lab technologist spends most of his time for the preparation of patient doses. Therefore, lowering the ionizing radiation exposure according to radiation protection protocols is of extreme importance in hot-lab. ^{99m}Tc and ^{131}I are the most commonly used radionuclides in the hot-lab of NORIN; they are stored in heavy shielding of lead walls and fume hood respectively [9].

For the upper-bound on radiation exposure rate, the United Nations' Scientific Committee on Effects of Atomic Radiation (UNSCEAR) has set an annual effective dose rate limit of 2.4 mSv per annum for the indoor facilities including research laboratories, offices, conference halls, lecture rooms, etc. The average occupational dose of workers in medical centers in the United States is 2.2 mSv per annum. About 94% of workers in medical centers get an annual dose less than 5 mSv (NUREG-0714 1979) [10]. There are studies that have reported locations with elevated radiation rates in Kerala, India; Yang Jian, China; and Ramsir, Iran as in [11]; as well as in Asia that raise the probability of stochastic effects. Maximum outdoor radiation levels have also been found in Malaysia and peak indoor radiation levels have been found in Iran and Hong Kong [12]. Pakistan Nuclear Regulatory Authority (PNRA) suggests the yearly dose limit for radiation workers not exceeding 20 mSv. In order to minimize the radiation exposure, three key considerations are distance, time, and shielding. However, in congested and small NM divisions, effectively using these parameters is a matter of special attention for technologists [13].

NORIN houses a number of facilities regarding diagnostics, therapy, and educational research on different types of cancers [14]. This hospital was framed with the goal to adopt modern research & development approaches for the management of cancers. The main department of this institute is the Nuclear Medicine & Allied Division. This division handles the diagnosis as well as treatment of tumors of numerous kinds. This department houses 02 dual-head SPECT gamma cameras (Infinia & Siemens). It also has a dedicated hot laboratory dealing with sealed as well as unsealed radiopharmaceuticals [15]. The procedures performed here involve Thyroid scans, whole-body scans, MUGA, bone scans, lung perfusion, renal scans, and myocardial perfusion. Hot-Lab technologist is deployed on rotation to minimize personnel exposure as per radiation protection plan of NORIN. This study aimed to assess the radiation levels in hot-laboratory where all radiopharmaceuticals are handled. This is possibly the area containing the highest radiation dose in the facility. A radiation protection program is implemented so that technologists are safe from acute hazards of radiation inside the hot-lab. Fig.1 shows the map of measurement points inside the hot-lab of NORIN, Nawabshah.

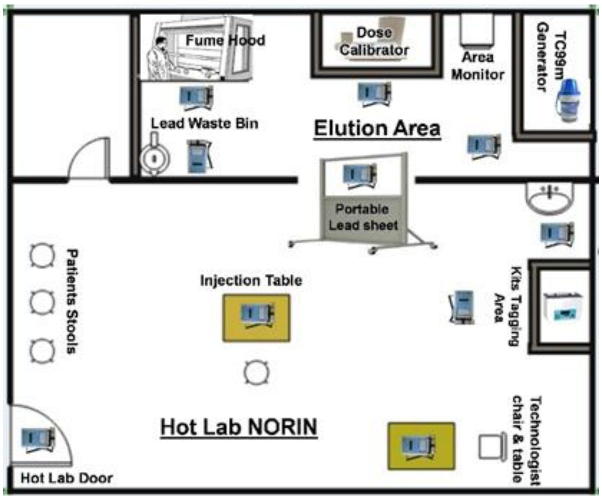

Fig.1 *Map of measurement points inside the hot-lab*

2. Material and Methods

NORIN Cancer Hospital is situated in the rural area of Sindh, Pakistan. The Nuclear Medicine division on average deals with around 120 cancer patients weekly. NM department is equipped with a specialized hot-lab where we store, prepare, tag and dispense all used radiopharmaceutical kits. For the sake of convenience for dose rate monitoring, the laboratory was divided into two halves i.e., elution area and injection area in order to follow the ALARA principle. Ten spots were selected for measurement of radiation levels are: Injection Table, Elution Table, Hot-Lab Door, Fume-hood proximity, Dose Calibrator surface, ^{99m}Tc-Generator, Technologist table, Sink, Waste bin and Kit-tagging area as shown in Fig. 2. Specially fabricated lead bricks were used for shielding around the critical areas, also illustrated in Fig. 2. The readings were recorded daily for one year (2021) and were used for the measurement of AEDR(Annual Effective Dose Rate).

Fig.2 *Locations of measurement inside lab of NORIN*

RM1001-RD LAMSE survey meter pre-calibrated from Secondary Standard Dosimetry Lab (SSDL) Islamabad, visualized in Fig.3, was used for this study. This model of survey meters is suitable for radiation surveys in medical centers. The measurements were recorded during working hours with the technologist performing routine tasks.

Fig.3 *RM1001-RD LAMSE survey meter*

The equivalent dose values were registered in micro-Sievert per hour from radiation survey meter directly. The results were then converted milli-Sievert per year (mSv/y). The occupancy factor (OF) of 0.8, as per recommendation of the UNSCEAR (2000), was used [16]. AEDR was determined with the given expression:

$$\mathrm{AEDR}\left(\frac{\mu Sv}{y}\right) = \mathrm{X}\left(\frac{\mu\mathrm{Sv}}{\mathrm{h}}\right) \times T \times OF \quad (1)$$

$$\mathrm{AEDR}\left(\frac{\mu Sv}{y}\right) = \mathrm{X}\left(\frac{\mu\mathrm{Sv}}{\mathrm{h}}\right) \times 8760 \times 0.8 \times 10^{-03} \quad (2)$$

X is the hourly dose rate, T is the number of total hours in one year (8760 hours) and OF denotes the occupancy factor (indoor = 0.8) [17]. To analyse data statistically, an independent T-test on SPSS 17 (SPSS Inc. USA) and values at a level of significance of 5% (P<0.05) were used (Table 1).

Table 1. Mean dose rates and AEDR (mSv/yr) and standard deviation at various points inside the hot-lab of NORIN.

Consoles	**Mean (µSv/h)**	**Mean (mSv/y)**	**AEDR (mSv/y)**	**P-Value (P < 0.05)**
Injection Table	0.187	1.63	1.31 ± 0.03	0.0250
Elution Table	0.209	1.83	1.47 ± 0.03	0.0330
Hot-lab Door	0.165	1.445	1.16 ± 0.05	0.0116
Near Fume-hood	0.158	1.387	1.11 ± 0.05	0.0314
Dose calibrator surface	0.151	1.330	1.06 ± 0.04	0.0225
Tc-99m Generator	0.195	1.708	1.37 ± 0.06	0.0263
Technologist Table	0.121	1.065	0.85 ± 0.03	0.0111
Sink	0.171	1.499	1.20 ± 0.03	0.0200
Waste bin	0.15	1.314	1.05 ± 0.03	0.0024
Kits Tagging Area	0.144	1.2629	1.01 ± 0.02	0.0010

3. Results and Discussion

The 10 measurement points inside the hot-lab of nuclear medicine were analysed for the present radiation hazards linked with the handling and administration of radiopharmaceuticals to patients at NORIN Nawabshah, Pakistan. Data were collected during working hours just behind the lead shielding bricks to estimate the live dose rate in the laboratory. The results of this study are represented in Table 1 with mean daily dose rates and

Annual Effective Dose Rate (mSv/y) with and P-values as well as standard errors. These results are relatively lower than international limits of background radiation due to strict following of radiation protection protocols as per PNRA & IAEA guidelines.

Fig.4 represents the daily dose rate values of aforementioned locations inside the hot-lab, also shown in Fig 2. The maximum average dose rate had the value of 0.209 µSv/h at the elution table and the minimum dose rate of 0.121 µSv/h was recorded at the technologist table.

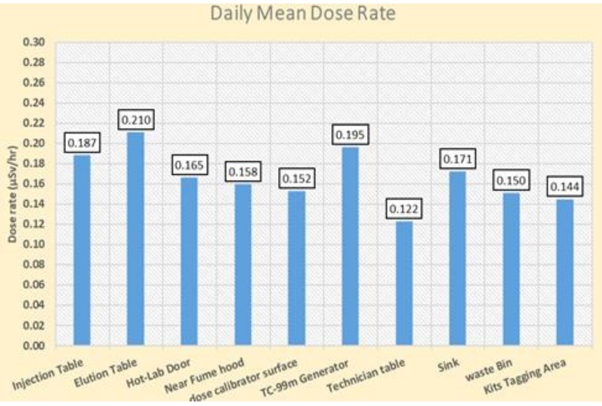

Fig.4 *Average daily dose rates at inside the hot- lab*

Fig. 5 represents AEDR values on the same selected sites and compares them with dose limit of UNSCEAR. Every bar displays a distinct location and AEDR values at the location are shown accordingly.

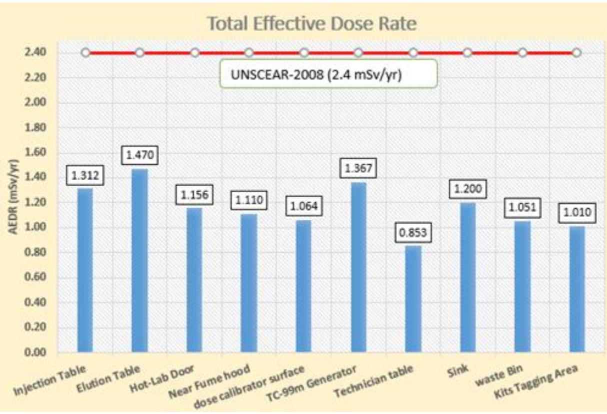

Fig.5 *Total Annual Effective Dose Rates at selected locations in hot-lab*

The highest dose rate was found at the elusion table with value of 1.470 ± 0.034 mSv/y. Second highest dose point was found at Tc-99m Generator with AEDR 1.367 ± 0.056 mSv/y. The least dose rate was found at the Technologist's table with AEDR of 0.853 ± 0.028 mSv/y. The graph clearly shows that even the highest AEDR value (1.470 mSv/y) is much lower than recommended annual dose limit of radiation workers. The annual dose limit from background radiation has the value of 2.4 mSv/y, much larger than our outcomes, as shown in Fig.5.

Fig. 6 shows the comparison of mean dose rate measured on daily basis in hot-lab with previous studies reported in literature. A study conducted by M.M. Ahasan (2004) shows a dose rate of 1.00 µSv/h in hot-lab of Centre of Nuclear Medicine & Ultrasound Bangladesh [5]. As per ALARA, the radiation exposure must be kept under 4 µSv/h in the hot-lab [5]. Daily Average dose rate in the nuclear medicine controlled areas (Hot-Lab) of university hospital, Ibadan documented 0.43 µSv/h dose rate by Akinlade Bidemi et al. [18]. The upper limit of 10 µSv/h on daily dose rate is recommended in code of practice for radiation protection in nuclear medicine (2010) by ministry of health, New Zealand [19]. Nosheen et. al. of nuclear medicine department, Zia-ud-Din Hospital Karachi reported a daily dose rate of 2.32 µSv/h [20]. Another study listed by Harding LK reported a mean dose rate of 7.50 µSv/h [21]. Khalid Alzimami et. al. (2015) reported mean dose rate of 10 µSv/h [22] in nuclear medicine. A researcher from Bangladesh improved hot-lab facility in nuclear medicine hospital of Dhaka and measured dose rate of 0.81 µSv/h after placement table-top bench shield [23]. According to NRC dose limits (10 CFR part 20) [24], radiation exposures must be lower than 20 µSv/h from a radiation source but the current study shows a comparatively negligible average daily mean dose rate of 0.21 µSv/h.

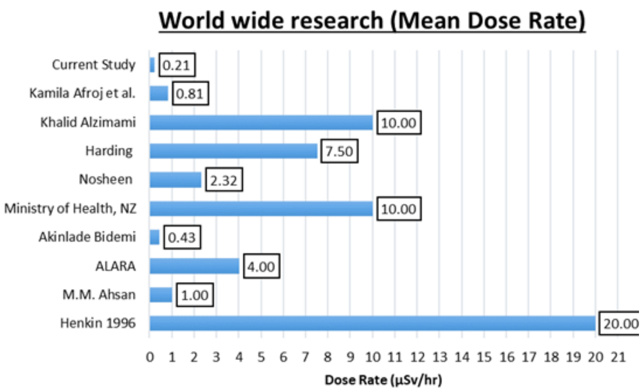

Fig.6 *Comparison of globally reported dose rates in Nuclear Medicine*

From above comparison, it is established that dose rates reported in this study are lower than in preceding works. Fig.7 shows annual effective dose rates previously reported and compares with present AEDRs. Fiona O. Robert et al. reported occupational exposure of 2.00 mSv/y in the Nuclear Medicine Department and PET centre Melbourne, Australia [25]. According to NUREG-0714 1979, the average occupational exposure of workers handling radiopharmaceuticals must be less than 5mSv/y [5]. A study carried out by M.M. Ahasan (2004) also shows a bit higher value of 1.90 mSv/y in the hot-lab of Centre of Nuclear Medicine & Ultrasound Bangladesh [5]. Mean AEDR in the hot-lab of university hospital, Ibadan documented 0.86 mSv/y by Akinlade Bidemi et al. [18] in Plateau State University, Nigeria's experimental labs. Pharmaceuticals installations in Nigeria [26] reported dose rate of 1.60 mSv/y by Nwankwo et al. (2014). In 2015, Felix BM. Robert et. al. found the ambient radiation dose levels at Plateau University Bookos and reported 1.54 mSv/y [27]. Mean Annual Effective Dose Rate at Federal University KATSINA state, Nigeria reported 1.41 mSv/y by Tersoo Atsue et al. Jwanbot et al. also reported higher values of ionizing radiation of 2.11 mSv/y in nuclear medicine departments of Jos Plateau state, Nigeria [28]. While the UNSCEAR (2008) allows the annual dose level of 2.4 mSv/y [29]. However, the AEDR found in this study is 1.47 mSv/y in hot-lab of NM & Allied Division of NORIN cancer hospital Nawabshah which is almost 58% of the safe of UNSCEAR 2008.

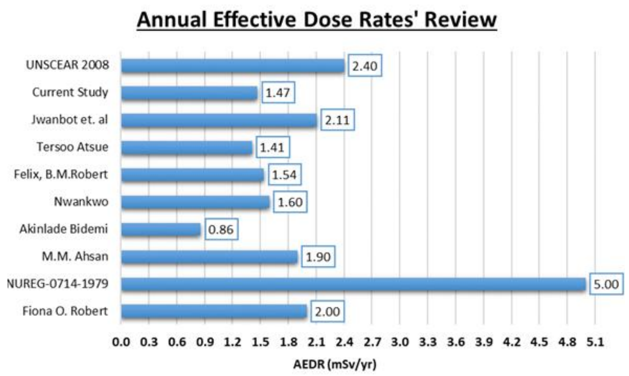

Fig.7 Review of AEDRs reported world-wide

Humans can not sense radiation and this makes radiation more dangerous. There is a variety of gadgets available for radiation measurement. It is easy to observe the results of radiation but the procedure for assessment is complicated. Even if the outcomes are not significant, a measurement must be done for keeping records. Areas like hot-lab which are used for supply and handling as well as storing radiopharmaceuticals are better known as controlled areas. The dose rate in such locations must not be above 10 µSv/h. The mean AEDR in the hot lab of NORIN, Nawabshah is very low as compared with the UNSCEAR recommended global average of 2.4 mSv/y and daily dose rate (µSv/h) is also negligible in comparison with [30] NRC dose limits (10 CFR part 20). This implies that the workers working inside the hot lab is radio-biologically safe from hazards of radiation.

4. Conclusion

In engaged nuclear medicine facilities, hot-lab workers are at a relatively elevated risk of getting exposed from stored radioactive source as well as from the patients who become mobile sources after having radiopharmaceuticals administered. This study concluded that there were no health risks to the hot-lab worker from radiation exposure. The dose rates were found between 0.121 and 0.209 µSv/h, while the AEDRs were measured between 0.853 and 1.47 mSv/y, which are very low as compared to the NRC dose limits (20 µSv/h) and UNSCEAR recommended global average dose of 2.4 mSv/y respectively. Our findings reaffirm that undue phobia regarding radiation among the hot-lab technologists must be placed in the proper perspective through proper education and training. However, we observed that the anxiety among radiation workers was still there but these results affirmed that the hot-lab technologist is radio-biologically safe. However special care must be taken in case of female workers where this issue becomes more sensitized because of fertility concerns. The author suggests that more studies should be done for a better comparative analysis. NORIN has adopted an excellent safety culture by compliance with the SOPs in the area of radiation protection.

Conflict of Interest

The authors have no conflict of interest

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References

[1] P. E. Ogola, W. M. Arika, D. W. Nyamai, K. O. Osano, and H. O. Rachuonyo, "Determination of background ionizing radiations in selected buildings in Nairobi County, Kenya, J. Nucl. Med. Radiat. Ther, 7,(3):289, (2016).

[2] M. Waqar, T. A. Afridi, Q. Soomro, and A. S. Abbasi, "Measurement of Ambient Ionizing Radiation Exposure in Operating Consoles of Radiation Modalities in Cancer Hospital", J. Eng. Res. Sci., 1(6):7-122022, [Online]. Available: DOI: 10.55708/js0106002. [3] R. E. Henkin, "Nuclear Medicine:2-Volume Set" V Mosby Elsevier, (2006).

[4] ORPGUIDE - Occupational Radiation Protection - IAEA Safety Standards Series, Vienna: Internatıonal Atomıc Energy Agency, (2000).

[5] M. M. Ahasan, “Assessment of radiation dose in nuclear medicine hot lab,” Int J Radiat Res., 2(2): 75-78, (2004).

[6] IAEA TECDOC-602, “Quality control of nuclear medicine instruments”, (1991). ISSN 1011–4289, International AtomicEnergy Agency, Vienna.

[7] IAEA Safety Standards, “Radiation Protection and Safety in Medical Uses of Ionizing Radiation” No. SSG-46, Internaiıonal Atomic Energy Agency, (2018).

[8] D. L. Bailey, et al., “Nuclear medicine physics: a handbook for teachers and students” IAEA, Vienna, (2014).

[9] M. Waqar, M. Shahban, Q. Soomro, M. E. Khan, “Performance of Tc-99m Generators in Terms of Molybdenum Contents Measured in NORIN Nawabshah, Pakistan (5 years’ Experience),” Iran. J. Sci. Technol. Trans. A Sci., 43(1,), 285–289, (2019).

[10] B. Brooks, S. McDonald, E. Richardson, “Occupational radiation exposure. Fifteenth and sixteenth annual reports, 1982 and 1983. Volumes 4 and 5,” NUREG-0714-Vols.4-5 ON: TI86900302, United States, (1985).

[11] S. S. Althoyaib and A. El-Taher, “The measurement of radon and radium concentrations in well water from Al-Jawaa, Saudi Arabia,” Journal of Natural Sciences and Mathematics, 7(2), 172-179, (2014).

[12] F. Alshahri, A. El-Taher, and A. E. A. Elzain, “Measurement of radon exhalation rate and annual effective dose from marine sediments, ras tanura, Saudi Arabia, using Cr-39 detectors,” Rom. J. Phys., Vol. 64, p. 811, (2019).

[13] A. Razaq, M. Waqar, Q. Soomro, and M. A. Javed, “Evaluation of radiation workers occupational doses for newly established medical center NORIN Nawabshah in Pakistan,” J Med Phys Biophys, vol. 3, no. 1, pp. 61–65, (2016).

[14] M. Waqar, M. Shahban, Q. Soomro, and M. N. Abro, “Institution-based assessment of cancer patients treated by external beam radiotherapy in the rural area of Sindh, Pakistan: Five years of data analysis,” Middle East J. Cancer, 9(3), 217–222, (2018).

[15] M. Waqar, M. Shahban, Q. Soomro, T. A. Afridi, N. Med, “Assessment of residual activities of Technetium-99m radiopharmaceuticals to plastic syringes in nuclear medicine scans : 1-year experience at NORIN” Pakistan Journal of Nuclear Medicine, 12(1):01–06 (2016).

[16] N. Y. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) NY (United States), Sources and effects of ionizing radiation UNSCEAR 2000 report to the General Assembly, with scientific annexes Volume I: Sources. United Nations (UN): UN, (2000).

[17] U. Rilwan, A. U. Maisalatee, M. Jafar, “Assessment of Indoor and Outdoor Radiation Exposure in Nasarawa General Hospital, Nasarawa State, Nigeria,” J. Radiat. Nucl. Appl. An Int. J., 6(3), 245–249, (2021).

[18] I. Akinlade Bidemi, O. Kelani Sherif, “Assessment of Radiation Dose in Nuclear Medicine Controlled Areas: Hot Lab, Injection and Isolated Rooms,” Journal of Advances in Medicine and Medical Research, 31(8): 1-6, (2019).

[19] New Zealand Ministry of Health - Office of Radiation Safety, “Code of Practice for Nuclear Medicine. ORS C2,” p. 30, (2019).

[20] N. Fatima, M. uz Zaman, M. K. Iqbal, A. Rameez, Q. Ain, “Exposure Rate in Hot Waiting Area of Small but Busy Nuclear Medicine Department: ‘Meter Matters,” PJR, vol. 26, no. 3, (2016).

[21] L. K. Harding, A. Bossuyt, S. Pellet, C. Reiners, and J. Talbot, “Radiation doses to those accompanying nuclear medicine department patients: a waiting room survey,” Eur. J. Nucl. Med., 21(11), 1223–1226, (1994).

[22] K. Alzimami, A. Sulieman, M. Alkhorayef, “Ambient and occuptional radiation dosimetry in nuclear medicine.”, Journal of Nuclear Medicine 56(3):1701, (2015).

[23] K. A. Quadir, N. Khatun, M. A. Hoque, A. Begum, “Improvement of Hot Laboratory Facilities in Nuclear Medicine,” Bangladesh J. Med. Phys., 5,(1), 37–40, (2012).

[24] E. Ibis, C. R. Wilson, B. D. Collier, G. Akansel, A. T. Isitman, and R. G. Yoss, “Iodine-131 contamination from thyroid cancer patients,” J. Nucl. Med., 33 (12), 2110–2115, (1992).

[25] F. O. Roberts et al., “Radiation dose to PET technologists and strategies to lower occupational exposure,” J. Nucl. Med. Technol., 33(1)1, 44–47, (2005).

[26] L. I. Nwankwo, D. F. Adeoti, A. J. Folarin, “Ionizing radiation measurements and assay of corresponding dose rate around bottling and pharmaceutical facilities in Ilorin, Nigeria,” J. Sci. Technol., 34 (2), 84–92, (2014).

[27] F. B. Masok, R. R. Dawam, E. W. Mangset, “Assessment of indoor and outdoor background radiation levels in Plateau State University Bokkos Jos, Nigeria”, Journal of Environment and Earth Science, 5(8), 2015.

[28] T. Atsue, J. Adegboyega, "Assessment of the Ambient Background Radiation Levels at the Take-Off Campus of Federal University Dutsin-Ma, Katsina State-Nigeria," FUDMA Journal of Science (FJS), 1(1),58-68, (2017).

[29] UNSCEAR, "Sources and effects of ionizing radiation, ANNEX B, Exposures from natural radiation sources," UNSCEAR 2000 REPORT, New York, (1)97–99, (2000).

[30] D. E. Lewis, E. Dickson, D. A. Hagemeyer, Occupational Radiation Exposure at Commercial Nuclear Power Reactors and Other Facilities 2007 Fortieth Annual Report, V 29. (2008).